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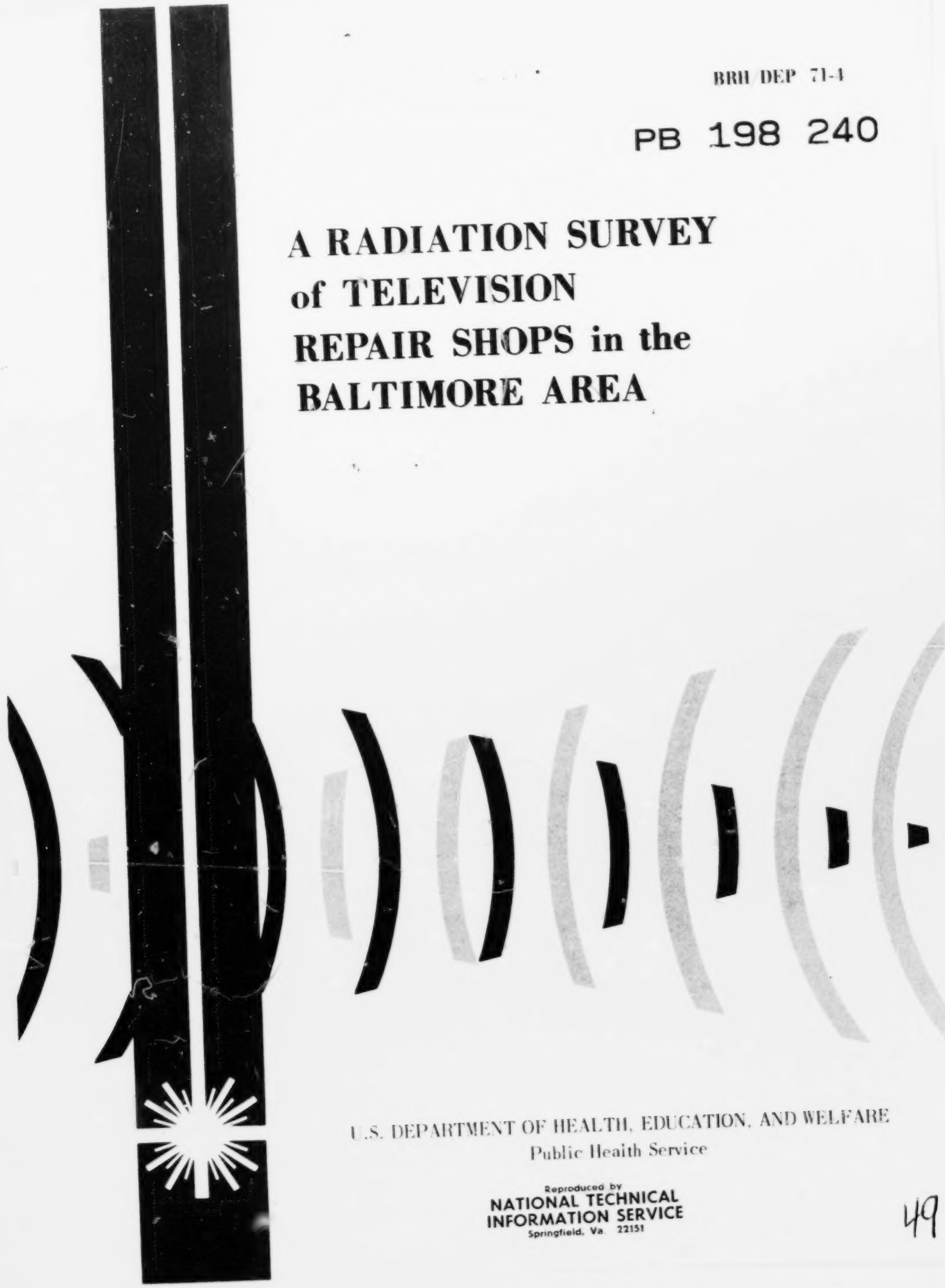
A RADIATION SURVEY of TELEVISION REPAIR SHOPS in the BALTIMORE AREA



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A RADIATION SURVEY of TELEVISION REPAIR SHOPS in the BALTIMORE AREA

John L. Wyatt, Jr.
Thomas M. Moore

Intelligence Branch
Division of Electronic Products

March 1971

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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FOREWORD

The Bureau of Radiological Health continues to carry out a national program designed to reduce the exposure of man to hazardous ionizing and nonionizing radiation.

Within the Bureau, the Division of Electronic Products (1) develops and administers performance standards for radiation emissions from electronic products, (2) studies and evaluates emissions of and conditions of exposure to electronic product radiation and intense magnetic fields, (3) conducts or supports research, training, development, and inspections to control and minimize such hazards, and (4) tests and evaluates the effectiveness of procedures and techniques for minimizing such exposures.

The Bureau publishes its findings in appropriate scientific journals and technical report and technical note series for the Bureau's divisions, offices, and laboratories.

The technical reports and notes of the Division of Electronic Products allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports and notes are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. They are also included in the collections of the Library of Congress and the National Technical Information Service.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The present Federal performance standard for television receivers specifies maximum allowable radiation levels near the surface of the receiver. This standard was promulgated to protect the television viewer from excessive radiation exposure. No attempt was made to restrict internal radiation emission in locations accessible to service technicians. Allowable radiation levels within the television receiver were not specified because little was known about what these levels might be and the particular situations in which they might occur.

At the suggestion of the Technical Electronic Products Radiation Safety Standards Committee, a television repair shop radiation survey was organized by the Division of Electronic Products with the cooperation of the Maryland State Department of Health and Mental Hygiene and the Electronic Industries Association. This report presents the results of the survey which was performed in the Baltimore, Maryland, area from March to October 1970.

Originally, the Baltimore survey was intended to be a pilot study which would be used to initiate a large scale survey. Since the data indicated no need to expand the study, this report may be regarded as the final action of this project.

Robert L. Elder, Sc.D.
Director
Division of Electronic Products

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ABSTRACT

A pilot study of the radiation exposure to television service technicians during the course of their work was performed in 70 Baltimore-area television repair shops from March to October 1970. In the first 25 shops, personnel dosimeters were distributed to the service technicians,and radiation exposure rate measurements were made on 58 color television receivers representing 15 different brands. In the remaining shops, no radiation measurements were made on receivers, but dosimeters were distributed to the technicians to enlarge the statistical base for personnel exposure determinations. The survey data indicated that the radiation doses received by the technicians were relatively low. Hence, it was concluded that a national survey does not appear necessary.

ACKNOWLEDGEMENTS

The authors wish to thank the following people for their assistance in the conduct of this survey: Mr. Thomas Ferguson of the Maryland State Department of Health and Mental Hygiene for the many visits he made to repair shops; Mrs. Jane Garry of the Product Testing and Evaluation Branch, DEP, for her help in preparing the dosimeters; and Mr. Pomeroy Skeeter of the Radiation Measurements and Calibration Branch, DEP, for his suggestions regarding dosimeter fabrication and badge identification and storage, and for performing readings on more than 2,000 TLD ribbons. In addition, the entire Intelligence Branch, DEP, provided invaluable assistance in the contacting of shops, scheduling of visits, and performance of surveys.

A RADIATION SURVEY OF TELEVISION REPAIR SHOPS IN THE BALTIMORE AREA

1. INTRODUCTION

A considerable amount of information has been gathered and published concerning the emission of x radiation from color television receivers. (1-10). In some instances, the radiation levels near the surface of the receivers were found to approach or exceed (1, 9, 10) the maximum levels recommended by the National Council on Radiation Protection and Measurements.[1] As a result, a Federal standard (11) limiting emissions to 0.5 mR/hr at a distance of 5 cm under various conditions of operation was promulgated and became effective on January 15, 1970.

Radiation from color television receivers has been found to originate in one or more of three locations: the picture tube, the shunt regulator tube, and the high-voltage rectifier tube. During the repair of color TV receivers it is often necessary for TV service technicians to work near these potential radiation sources while the receiver is operating, without the protection normally afforded by the receiver cabinet and internal shielding. For this reason, studies have been made, both by the Federal government (12) and by private industry (13) of the radiation dose received by television service technicians in the course of their work. At the suggestion of the Technical Electronic Products Radiation Safety Standards Committee,[2] a survey was performed by the Division of Electronic Products (DEP), in cooperation with the Electronic Industries Association and the Maryland State Department of Health and Mental Hygiene, to investigate more thoroughly both the exposure rates around various portions of receivers where technicians frequently work and the radiation levels to which they might be exposed.

Letters were sent to the 207 television repair shops listed in the yellow pages of the Baltimore, Maryland, telephone directory explaining the purpose of the survey and asking if the shop would be interested in participating. The interested shops returned an enclosed post card addressed to the Division of Electronic Products. The 70 Baltimore-area TV repair shops that returned the card and could be contacted were surveyed between March and October 1970.

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[1] The NCRP recommendation states "...the exposure rate at any readily accessible point 5 cm from the surface of any home television receiver shall not exceed 0.5 mR/hr under normal operating conditions."

[2] Members of the Technical Electronic Products Radiation Safety Standards Committee are appointed by the Secretary, DHEW, under the authority of the Radiation Control for Health and Safety Act of 1968.

2. SURVEY METHODS AND INSTRUMENTATION

In the first 25 of the 70 Baltimore-area shops surveyed, radiation measurements were made on all operable receivers and test rigs in a shop at the time of the visit. In addition, the high-voltage setting on outgoing receivers was measured, the shop's high-voltage meter was checked against a calibrated electrostatic kilovoltmeter, detailed questions were asked about service practices in the shop, and each service technician was given several radiation badges to wear for a week. (See forms 1, 2, 3, and 5 of appendix A.) The purpose of this first type of survey was to measure radiation exposure to the technician and to determine what conditions might produce that exposure. In the remaining 45 shops, radiation badges were distributed and a minimum of other information was collected. (See forms 4 and 5 of appendix A.) The purpose of this second type of survey was to furnish an enlarged statistical base for our conclusions concerning radiation exposure to service technicians.

2.1 EXTERNAL RECEIVER RADIATION MEASUREMENTS

In the first 25 shops surveyed, every operable receiver was scanned with a large-area Geiger-Mueller survey instrument (fig.1) designed by Mr. Richard Stoms of DEP specifically for measuring radiation from color television receivers (14). The radiation-sensitive element of this instrument is an array of six Victoreen type-1B85 Geiger-Mueller tubes connected to a common high-voltage supply. Individual solid-state circuits measure the current through each detector. The outputs of the six readout circuits are connected to the input of the meter circuit in such a way that the meter indicates only the reading of the detector with the highest output.

Each instrument was calibrated at several different photon energies. Calibrations were made both before and after the survey and were found to be in agreement. The energy dependence of these instruments is indicated by the calibration data given in appendix B. The calibration factor used was the one indicated for 26.4 KeV x rays.

Each receiver in the first 25 shops was scanned on all six sides with the large-area Stoms instrument. The brightness control was adjusted to maximize any reading obtained, and the highest reading was recorded along with its location. The line voltage used was that found in the shop at the time of the survey.

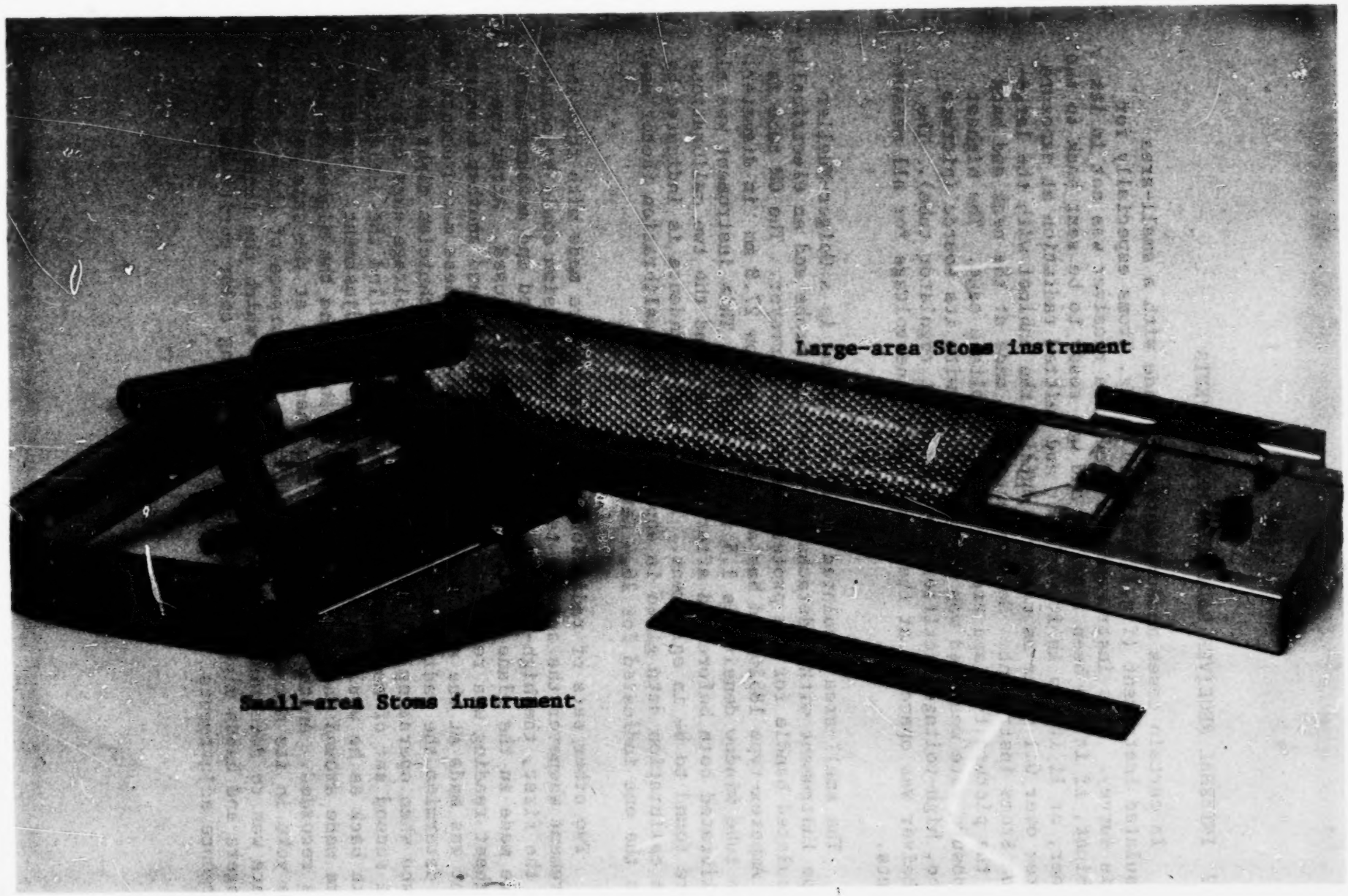

Figure 1. Large-area and small-area Stoms survey instruments.

2.2 INTERNAL RECEIVER RADIATION MEASUREMENTS

In certain cases measurements were made with a small-area insulated instrument (fig. 1) designed by Mr. Stoms especially for this survey. This instrument was used if a receiver was not in its cabinet, if it had been repaired and was ready to be sent back to the owner, or if it was in its cabinet and emitted radiation at exposure rates over 0.1 mR/hr as measured outside the cabinet with the large-area Stoms instrument. Measurements were made at the neck and back of the picture tube and around the high-voltage cage. The highest exposure rate measured was recorded along with its source (picture tube, high-voltage rectifier tube, or shunt regulator tube). The receiver was operated at the normal shop line voltage for all measurements.

The small-area insulated Stoms instrument is a Geiger-Mueller type instrument with a detachable end-window probe and an electrically insulated handle for the protection of the surveyor. The GM tube is an Amperex-type 18526 and has a mica end window 27.8 mm in diameter. The tube window density is 1.5 to 2.0 mg/cm^2. This instrument was also calibrated both before and after the survey, and the two calibrations were found to be in agreement. The energy dependence is indicated by the calibration data given in appendix B. The calibration factor used was the one indicated for 26.4 KeV.

Two other sets of radiation measurements were made with this instrument whenever the service technician's permission could be obtained. In the first, the high-voltage cage door was opened and measurements were made in the plane the door would occupy if closed. After the highest reading was recorded, the door was closed and another measurement was made at the same point. The purpose of these measurements was to determine the radiation levels to which the technician might be exposed when operating the receiver with the high-voltage cage open. In the second set of measurements, the technician pulled the deflection yoke back as he would in making a color purity adjustment. Measurements were made around the neck of the picture tube, and the highest reading was recorded. Another measurement was then made at the same point with the yoke in its normal forward position. The purpose of these measurements was to determine the radiation levels to which the technician's fingers and hands might be exposed while making color purity and convergence adjustments.

2.3 HIGH-VOLTAGE MEASUREMENTS

High-voltage measurements were made on all outgoing receivers with a Hallmark Standards, Inc. Model KVE electrostatic kilovoltmeter. The meter was used to determine if the shop had set the high voltage on outgoing receivers to the level recommended by the manufacturer. Measurements were made with the brightness control set to minimum, a condition which approximates zero beam current.

The electrostatic meter itself was calibrated both before and after the survey using a Universal Voltronics Corp. high-voltage d.c. power supply, model BRE 60 50 R2. The two calibrations were found to be in agreement.

In addition, all high-voltage measuring devices in the shop were checked against the electrostatic meter. Since it was not practical to carry a calibrated high-voltage supply into each shop, a color television receiver already in the shop was used as the d.c. high-voltage source. In performing this test, the electrostatic kilovoltmeter and the shop's high-voltage probe were connected in parallel between the picture tube anode and chassis ground. The station selector was turned to an unused channel, and the brightness and/or high-voltage control was varied until a steady voltage between 19 kV and 27 kV was obtained. The readings from both meters were then recorded to provide a one-point check on the shop's meter in the high-voltage range most commonly found in color TV receivers.

2.4 PERSONNEL DOSIMETRY

Personnel dosimetry was accomplished by means of TLD (thermoluminescent dosimeter) ribbons. The TLD material, calcium fluoride, is available commercially as TLD 200 in 1/8-inch by 1/8-inch by 0.035-inch ribbons from the Harshaw Chemical Co.

The ribbons were encased in ring badges, eyeglass badges, and lapel badges in an attempt to measure exposure to the fingers, eyes, and upper trunk. The various types of badges are shown in figure 2. No attempt was made to directly measure gonadal exposure.

Each badge contained two crystals rather than one in order to increase accuracy of measurement and to enable recognition of an occasional faulty crystal. The reading for any badge was taken to be the mean of the readings obtained from the two ribbons in that badge. In the few cases where the higher of the two readings was more than 1.5 times the lower reading, data from the entire badge were discarded. This discrepancy occurred in 5 of the 284 badges read.

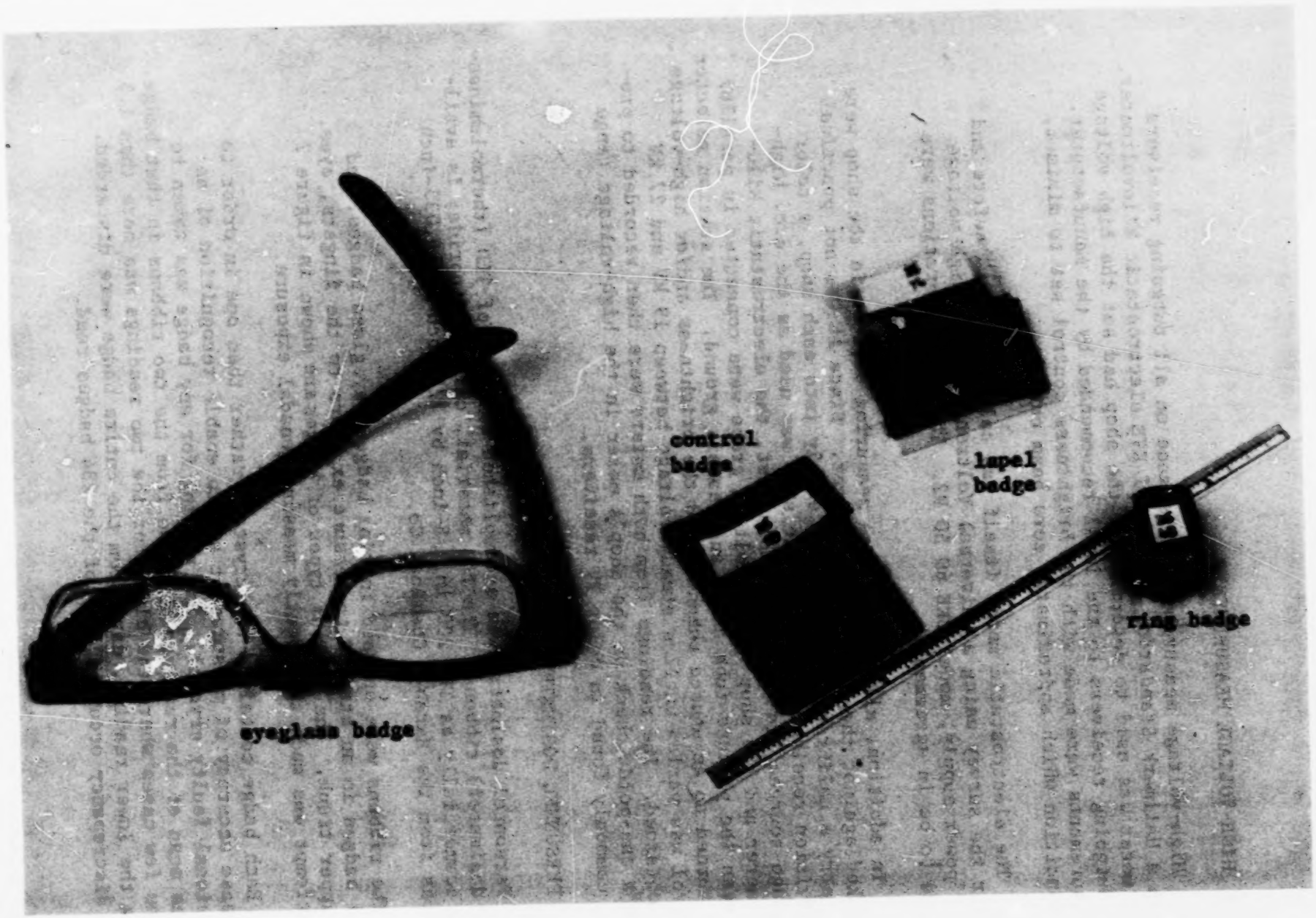

Figure 2. Personnel dosimeter badges

The ring badges were made by heat sealing the ribbons in a thin layer of clear plastic which was then sewn into an elastic ring. The rings were made in various sizes in an attempt to individually fit each service technician.

The lapel badges were made by heat sealing the ribbons in thin, clear plastic envelopes. The envelopes were enclosed in plastic name tag holders which could be pinned onto the technician's pocket.

The eyeglass badges were made by inserting two ribbons into a Tygon® capsule and heat sealing it at both ends. The capsule was taped to the bridge of the technician's glasses.

The portions of the badges containing the ribbons were wrapped in thin, black plastic electrician's tape to avoid any possible spurious readings from visible or ultraviolet light. It was assumed that the thin layers of plastic and electrician's tape did not significantly affect the response of the TLDs.

Since the crystals were annealed and calibrated in batches of 200 and their characteristics varied somewhat from one batch to another, each ring and lapel badge was clearly labeled with the batch number, the batch color code, and an individual badge number. Records of the eyeglass badges, which were too small to label, were carefully maintained.

Because the variations in natural background radiation from one shop to another were often larger than the relatively small radiation emissions to be expected from color TV receivers, a control badge was placed in each shop as far as practicable from the receivers to measure local background radiation. The control badges contained 10 TLD ribbons and were also wrapped in black tape. In data processing, the mean reading from these 10 ribbons was subtracted from the badge readings in that shop to determine the amount of radiation which could be attributed to the receivers. Care was taken to ensure that all ribbons in any given shop, including those in the control badge, were taken from the same batch. The control badges were stored and transported to and from the shops in the same box as the personnel badges to compensate for the effects of any incidental radiation received in transit.

Each service technician was given a ring badge and a lapel badge to wear. In addition, each technician who wore glasses was given an eyeglass badge which was taped to the bridge of his glasses by the surveyor.

The technicians were instructed to wear the ring and lapel badges all day but to leave them in the shop at night, rather than take them home, to avoid added uncertainty as to the source of any readings. They were, however, allowed to keep the eyeglass badge on at all times if they wished because of the difficulty involved in removing it. The badges were left with the technicians for seven days and then picked up by a surveyor. No badges were sent through the mail. When the badges were picked up, each technician was questioned about the possibility of radiation exposure from sources other than color TV receivers; e.g., medical x rays.

The technical procedures involved in reading and calibrating the TLDs are given in appendix C.

3. SURVEY DATA

3.1 X-RADIATION EMISSION

Measurements were made of x-radiation exposure rates from 15 brands of TV receivers in 24 different shops. In the twenty-fifth, no operable color receivers were found. In all, 58 individual receivers were surveyed. Of these, 45 produced no measurable emissions.

The large-area Stoms instrument was used to measure external radiation emissions from 46 receivers in which the chassis was inside the cabinet when the survey was made. No radiation was detected from 39 of these receivers. Five produced exposure rates that were measurable but less than 0.5 mR/hr. Two receivers in two different shops emitted more than 0.5 mR/hr at 5 cm from the surface. The first of these two receivers emitted 1.75 mR/hr from the left-hand side, and the high voltage at zero beam was found to be 30.7 kV rather than 25.0 kV as recommended by the manufacturer. The second receiver emitted 1.1 mR/hr from the top, and its high voltage at zero beam was found to be 26.8 kV rather than 22.0 kV as recommended by the manufacturer. Both of these receivers had been repaired and would have been returned to the customer in the condition found by the surveyors. In both cases, the instrument readings fell to background when the high voltage was properly adjusted.

The small-area insulated Stoms instrument was used to make internal radiation measurements on 41 receivers. Of these, 31 emitted no measurable radiation, five produced exposure rates that were measurable but less than 0.5 mR/hr, and five emitted more than 0.5 mR/hr. In four of the five that emitted more than 0.5 mR/hr the source of radiation was the neck or back of the picture tube, and in the remaining one the source was the shunt regulator tube. The highest internal exposure rate found was 2.0 mR/hr.

The small-area insulated Stoms instrument was used to perform two special tests where the service technician's permission could be obtained. In the first, the high-voltage cage door was opened and radiation measurements were taken in the plane the door had occupied when closed. This test was made on 22 receivers. In 17 cases no measurable increase in radiation was found with the door open, and in no case did the increase exceed 0.5 mR/hr.

In one shop where this test had been performed and no radiation increase had been detected, the technician volunteered to remove the metal shield around the shunt regulator tube. This shield was attached to the chassis with rivets and is not normally removed during servicing. Exposure rates up to 5.0 mR/hr were observed around the 6BK4 shunt regulator while the shield was removed. Instrument readings fell to background with the shield replaced. The high voltage on the receiver had been correctly set to the manufacturer's recommended value of 25 kV at zero beam current.

In the second special test the deflection yoke was withdrawn as far as possible, and radiation measurements were made around the neck of the picture tube. The yoke was then slid back into place, and a second measurement was made in the same location. This test was performed on 12 receivers, and 11 showed no measurable increase in radiation. One receiver, however, emitted 3.8 mR/hr around the picture tube neck with the yoke retracted. The instrument reading fell back to zero when the yoke was replaced.

Tables 1 through 4 summarize the x-radiation emission data obtained during the survey.

Table 1. Radiation measurement data for external scan of receiver in cabinet.

Number of receivers surveyed 46

Number of receivers emitting no measurable external radiation 39

Number of receivers emitting measurable external radiation less than 0.5 mR/hr. 5

Number of receivers emitting more than 0.5 mR/hr external radiation 2

Data for the two receivers emitting more than 0.5 mR/hr external radiation:

	Receiver No. 1	Receiver No. 2
Highest external exposure rate	1.1 mR/hr	1.75 mR/hr
Location of highest reading	top	left side
Manufacturer's recommended high voltage at zero beam current	22.0 kV	25.0 kV
Measured high voltage at zero beam current	26.8 kV	30.7 kV

Table 2. Radiation measurement data for internal scan of receiver chassis.

Number of receivers surveyed. 41

Number of receivers emitting no measurable internal radiation. 31

Number of receivers emitting measurable internal radiation less than 0.5 mR/hr 5

Number of receivers emitting more than 0.5 mR/hr internal radiation 5

Data for the five receivers emitting more than 0.5 mR/hr internal radiation:

	Receiver No. 1	Receiver No. 2	Receiver No. 3	Receiver No. 4	Receiver No. 5
Highest internal exposure rate	0.55 mR/hr	0.7 mR/hr	0.7 mR/hr	1.5 mR/hr	2.0 mR/hr
Radiation source	Picture tube funnel	Picture tube funnel	Shunt regulator tube	Picture tube funnel	Picture tube funnel
Manufacturer's recommended high voltage at zero beam current	25.0 kV	24.0 kV	--	22.0 kV	25.0 kV
Measured high voltage at zero beam current	30.0 kV	24.4 kV	--	26.8 kV	30.7 kV

Table 3. Radiation measurement data for tests involving opening of the high-voltage cage door.

Number of receivers tested	22
Number of receivers in which no measurable radiation increase was observed	17
Number of receivers in which radiation increase was measurable but less than 0.5 mR/hr	5
Number of receivers in which radiation increase exceeded 0.5 mR/hr	0

Table 4. Radiation measurement data for tests involving retraction of deflection yoke.

Number of receivers tested	12
Number of receivers in which no measurable radiation increase was observed	11
Number of receivers in which radiation increase was measurable but less than 0.5 mR/hr	0
Number of receivers in which radiation increase exceeded 0.5 mR/hr	1[a]

[a]For this one receiver, the exposure rate measured with the yoke retracted was 3.8 mR/hr. No radiation was measured with the yoke in place.

3.2 HIGH-VOLTAGE METERS

One or more high-voltage meters in 16 different shops were checked for accuracy against a calibrated electrostatic kilovoltmeter. Nine of the shops visited had no high-voltage meter on hand when the surveyors arrived. A total of 30 meters from six manufacturers was tested.

Fourteen meters used by the repair shops were the Pomona 2900, while six were the newer Pomona 2900A. Both models are portable plastic probes containing a large resistor in series with the meter which indicates 30 kV full scale. Nineteen of the 20 Pomona meters were in error by less than 1.4 kV. One meter, however, indicated a reading that was low by 6.3 kV or 24 percent. This meter had not been obviously damaged, and the repairman was not aware that it was in error.

This Pomona 2900 was the only high-voltage meter that read low by more than 10 percent. In the shop that owned this probe radiation measurements were made on one receiver which was still under repair and two which were ready to be returned to their owners. No detectable emissions were found.

Results of the high-voltage meter tests are summarized in table 5.

Table 5. Data for tests of high-voltage meters.

Meter type	Voltage indicated by electrostatic kilovoltmeter (V)	Voltage indicated by shop's meter (Vs)	Error (Vs-V)	Percent error $\frac{Vs-V}{V} \times 100$
Pomona 2900	26.3	20.0	-6.3	-24.0
"	22.3	21.0[a]	-1.3	-5.8
"	23.3	22.2	-1.1	-4.7
"	24.6	23.5	-1.1	-4.5
"	25.8	24.8	-1.0	-3.9
"	21.6	21.0	-0.6	-2.8
"	23.5	23.0	-0.5	-2.1
"	24.2	24.0	-0.2	-0.8
"	26.2	26.0	-0.2	-0.8
"	25.0	25.0	0.0	0.0
"	19.5	19.7	+0.2	+1.0
"	20.9	21.3	+0.4	+1.9
"	23.1	23.8	+0.7	+3.0
"	23.3	24.0	+0.7	+3.0
Pomona 2900A	25.2	24.0	-1.2	-4.8
"	21.0	20.5	-0.5	-2.4
"	22.0	21.5	-0.5	-2.3
"	25.2	25.0	-0.2	-0.8

[a] Meter showed a great deal of drift and instability. The reading recorded represents surveyor's attempt at visual averaging.

Table 5. Data for tests of high-voltage meters.(continued)

Meter type	Voltage indicated by electrostatic kilovoltmeter (V)	Voltage indicated by shop's meter (Vs)	Error (Vs-V)	Percent error $\frac{Vs-V}{V} \times 100$
Pomona 2900A	25.2	25.0	-0.2	-0.8
"	24.9	25.0	+0.1	+0.4
Simpson VOM (Model 260, Series 3) with Simpson 50 kV probe	25.2	24.6	-0.6	-2.4
"	22.0	23.0	+1.0	+4.6
B and K VTVM with Dynascan AV-2A probe	24.4	22.5[a]	-1.9	-7.8
"	24.3	23.5	-0.8	-3.3
RCA Junior Voltohmyst with RCA WG289 probe	22.8	20.5	-2.3	-10.0
B and K HV 30 probe	25.8	23.5	-2.3	-8.9
Simpson 270 VOM with Simpson High Voltage Probe	24.7	25.0	+0.3	+1.2
Simpson VOM (Model 260) with RCA probe	22.9	23.4	+0.5	+2.2
EICO High Voltage probe	22.3	23.0[a]	+0.7	+3.1
Colonial Kilovoltmeter	23.3	26.3	+3.0	+12.9

[a]Meter showed a great deal of drift and instability. The reading recorded represents surveyor's attempt at visual averaging.

3.3 DOSIMETRY

Personnel dosimeters were distributed to service technicians in 70 shops and successfully collected and read from those in 59 shops. In nine of the 11 shops for which data are not reported here, the control badges had been taken from one batch and the personnel badges from another, thus precluding an accurate determination of personnel exposure. Because of an oversight no control badges were left in the remaining two shops.

Table 6 summarizes the results of personnel exposure measurements.

Table 6. Personnel exposure data from TLD measurements.

Dosimeter Type	Number of badges read	Average exposure above natural background over a 1-week period (mR)	Highest exposure above natural background over a 1-week period (mR)
Ring Badge	121	0.01	0.23
Eyeglass Badge	25	0.04	0.30
Lapel Badge	133	0.02	0.25

3.4 SERVICE TECHNIQUES

In the first 25 shops surveyed, detailed questions were asked about service and repair techniques. All service technicians agreed that it is sometimes necessary to operate the receiver with the high-voltage cage door open. There seems to be no alternate procedure for locating faulty components or wiring in the high-voltage section.

Another procedure which might produce radiation exposure to service technicians is the practice of operating the receiver at an elevated line voltage for the purpose of "cooking out" weak or intermittent components. Technicians in 25 shops were asked whether they ever use this procedure, and in eight shops one or more technicians stated that they did. There is a danger that "cooking" a receiver may raise the high voltage enough to produce x radiation, and it is possible that a set might be operated in this way for several hours. Some shops locate intermittent failures due to heat by using an electric blanket or soldering iron and thereby avoid any increased radiation danger.

4. CONCLUSIONS

In both cases encountered in which radiation leakage at the outside of a receiver cabinet exceeded 0.5 mR/hr, the leakage could be corrected by adjusting the high voltage to the recommended level. In most cases radiation leakage inside the cabinet could be corrected in the same way. We conclude, therefore, that the most important and effective step toward reducing radiation exposure to service technicians and homeowners alike would be a service-wide program of careful high-voltage measurement and control. Twenty-seven of the 30 high-voltage meters checked in this survey were accurate to within better than 10 percent and would therefore be adequate for this purpose.

The difficulty lies partly in the inadequate procedures used by some service technicians to monitor the high voltage. Many technicians stated that they adjust high voltage by "feel", intuition, or the appearance of the picture rather than by use of a measuring instrument. In addition, not all technicians make the high-voltage adjustment at zero beam current as recommended by most manufacturers.

The feasibility of a high-voltage control program has been demonstrated in one of the larger service shops visited during this survey. Each time a technician in this shop adjusts the high voltage on a receiver, he seals the control with a paper sticker bearing his initials and the date. Thus, it is easy for a technician to determine whether a high-voltage control has been adjusted by the owner or another technician. It is of interest to note that no excessive high-voltage measurements were observed by the surveyors in the repair shop that used this technique.

It is recognized that a possible source of excessive high voltage on a receiver in the viewer's home is a difference between the line voltages in the repair shop and in the home. No attempt was made in this survey to investigate this problem.

Most repairmen reported receiving literature from several manufacturers on x-radiation emissions. They seemed well informed of the causes of radiation (excessive high voltage, open door to the high-voltage cage) and the sources of radiation (picture tube, shunt regulator tube, and high-voltage rectifier tube). A certain bias in the survey may be reflected in this conclusion, since the shops visited were the ones that returned our card and expressed an interest in being surveyed.

In general, service technicians were skeptical of the danger in x radiation from color television. Their skepticism was based on their experience of repairing color receivers for years without suffering any apparent ill effects and their observation that, whatever the dangers from x radiation might be, the hazard from the high voltages to which they are frequently exposed is likely to be greater.

The technicians were in general quite cooperative and were found to be wearing the badges when the surveyors returned to collect them. It was quite easy to tell if the ring badges, at least, had been worn regularly, because the paper labels on the ring badges were not protected by plastic. If the label remained perfectly clean, it was clear that the ring had not been worn. This was seldom found to be the case.

Note that the radiation doses received by the technicians (see TLD data in table 6) are relatively low. The low values can be attributed to several factors. One is the possibility that the technician may spend only a short time in close proximity to any given x-ray source in a receiver. A second is that exposure rates decrease rapidly with distance from the source, especially for high-voltage rectifier and shunt regulator tubes. And a third is that color television receivers of recent manufacture tend, on the whole, to emit less radiation than older sets (1, 15, 16).

Although the Baltimore survey was originally intended as a pilot study to initiate a nationwide survey, the data collected indicate that the public health significance of radiation exposure to television service technicians is minimal. Hence, no further surveys of repair shops are planned.

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APPENDIX A

SURVEY FORMS

5/27/70

Shop ID # [| | | |] (1-4)

Form # [1] (5)

Card Sequence # [1] (6)

Team ID # [| |] (7-8)

TV Repair Shop Pilot Survey

Facility Form

Date_____

1. Shop Name_____
   Shop Manager_____
   Street Address_____
   City, State_____
   Phone_____

2. Population Category
   Within City limits ___ W
   Suburban ___ S
   Town ___ T (9)
   Rural ___ R

3. Is the shop affiliated with a manufacturer? If so, list manufacturers and describe affiliation.
   Yes ___ Y (10)
   No ___ N
   _____
   _____
   _____

4. Number of full time repairmen [| |] (11-12)
   Number of part time repairmen [| |] (13-14)

5. Average number of receivers serviced per week in shop
   color [| |] (15-16)
   black and white [| |] (17-18)

6. Average number of receivers serviced per week in homes
   color [| |] (19-20)
   black and white [| |] (21-22)

7. Do servicemen ever adjust voltage in high voltage section to higher than recommended values? If so, for what purpose?
   Yes ___ Y (23)
   No ___ N
   _____
   _____
   _____
   If so, is adjustment temporary or permanent?
   Temporary ___ T
   Permanent ___ P (24)
   Both ___ B
   Comments_____
   _____
   _____
   _____

2

8. Do servicemen ever operate sets at a higher than normal line voltage?
   If so, why?_____
   Yes ___ Y (25)
   No ___ N
   _____
   _____

9. Do servicemen ever operate receiver with high voltage shielding removed?
   If so, for what purpose?_____
   Yes ___ Y (26)
   No ___ N
   Some do ___ S
   _____
   _____

10. Are servicemen aware that excessive voltage can cause X-ray production?
    Comments_____
    Yes ___ Y (27)
    No ___ N
    Some are ___ S
    _____
    _____

11. Are servicemen aware of the purpose of X-ray shielding?
    Comments_____
    Yes ___ Y
    No ___ N (28)
    Some are ___ S
    _____
    _____

12. Has shop received written material from any manufacturers on TV radiation emission?
    Comments_____
    Yes ___ Y (29)
    No ___ N
    _____
    If so, from what manufacturers?_____
    _____
    _____

13. Is the high voltage setting made at minimum brightness? If not, explain._____
    Yes ___ Y (30)
    No ___ N
    Sometimes ___ S
    _____
    _____

14. Kind of high voltage measurement device used in shop.
    If other, explain_____
    Voltmeter ___ V
    Light ___ L (31-32)
    Other ___ O
    None ___ N
    _____
    _____
    Brand name, model, and year of purchase of high voltage measurement device _____
    _____
    _____

3

15. Have measurement devices been calibrated since purchase?
    Yes ___ Y
    No ___ N
    No Measurement Devices ___ X (33)
    Some have ___ S
    Unknown ___ U

16. Voltage as measured with shop's device
    Voltage as measured with BRH probe
    Device A [| |] [|] kV
    [| |] [|] kV (34-39)

    Voltage as measured with shop's device
    Voltage as measured with BRH probe
    Device B [| |] [|] kV
    [| |] [|] kV (40-45)

    Voltage as measured with shop's device
    Voltage as measured with BRH probe
    Device C [| |] [|] kV
    [| |] [|] kV (46-51)

    Voltage as measured with shop's device
    Voltage as measured with BRH probe
    Device D [| |] [|] kV
    [| |] [|] kV (52-57)

    Voltage as measured with shop's device
    Voltage as measured with BRH probe
    Device E [| |] [|] kV
    [| |] [|] kV (58-63)

17. Control Badge batch number [| |] (64-65)

4

Shop ID # [| | | |] (1-4)

Form # [1] (5)

Card Sequence # [2] (6)

17. Control Badge number [| |] (7-8)

Crystal #1 First reading [| | | |] (9-12)
Second reading [| |] (13-14)

Crystal #2 First reading [| | | |] (15-18)
Second reading [| |] (19-20)

Crystal #3 First reading [| | | |] (21-24)
Second reading [| |] (25-26)

Crystal #4 First reading [| | | |] (27-30)
Second reading [| |] (31-32)

Crystal #5 First reading [| | | |] (33-36)
Second reading [| |] (37-38)

Crystal #6 First reading [| | | |] (39-42)
Second reading [| |] (43-44)

Crystal #7 First reading [| | | |] (45-48)
Second reading [| |] (49-50)

Crystal #8 First reading [| | | |] (51-54)
Second reading [| |] (55-56)

Crystal #9 First reading [| | | |] (57-60)
Second reading [| |] (61-62)

Crystal #10 First reading [| | | |] (63-66)
Second reading [| |] (67-68)

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4/2/70

Shop ID # ⌊_⌊_⌊_⌊_⌋ (1-4)

Form # ⌊2⌋ (5)

Card Sequence ⌊1⌋ (6)

Receiver # ⌊_⌊_⌋ of ⌊_⌊_⌋ (7-10)

TV Repair Shop Pilot Survey

Receiver Survey Form

1. Receiver brand code ⌊_⌊_⌊_⌊_⌋ (11-14)

2. Receiver operating normally
   Yes ___ Y (15)
   No ___ N

3. Receiver status
   Comments _____
   Incoming ___ I
   Under Repair ___ U (16)
   Outgoing ___ O

4. Is chassis in cabinet?
   Yes ___ Y (17)
   No ___ N

5. Maximum external reading (if chassis in cabinet) ⌊_⌊_⌋ . ⌊_⌋ mR/hr (18-20)
   Location Code
   Stoms Meter # _____
   Unconverted Net Reading _____ ⌊_⌊_⌊_⌋ (21-23)

6. Maximum internal reading (for sets with chassis not in cabinet, for sets radiating above 0.1 mR/hr externally, and for outgoing sets) ⌊_⌊_⌊_⌋ ⌊_⌋ mR/hr (24-27)
   Internal Meter # _____
   Unconverted Net Reading _____
   Source
   Picture tube ___ P
   Shunt regulator ___ S (28-30)
   Rectifier tube ___ R
   Unknown ___ U
   No reading ___ N

7. (Optional) Highest reading around high voltage cage with shield removed. ⌊_⌊_⌊_⌋ . ⌊_⌋ mR/hr (31-34)
   Unconverted Net Reading _____
   Reading at the same position with the shield in place. ⌊_⌊_⌊_⌋ . ⌊_⌋ mR/hr (35-38)
   Unconverted Net Reading _____
   Comments _____

8. (Optional) Highest reading around the neck of the picture tube with the deflection yoke retracted. ⌊_⌊_⌊_⌋ . ⌊_⌋ mR/hr (39-42)
   Unconverted Net Reading _____
   Reading at the same place with the deflection yoke in normal position. ⌊_⌊_⌊_⌋ . ⌊_⌋ mR/hr (43-46)
   Unconverted Net Reading _____
   Comments _____

4/2/70

9. High voltage setting intended (outgoing receivers only) ⌊_⌊_⌋ . ⌊_⌋ kV (47-49)
   Measured high voltage (at minimum brightness) ⌊_⌊_⌋ . ⌊_⌋ kV (50-52)

10. (To be completed only for sets radiating at levels above 0.1 mR/hr externally or 0.5 mR/hr internally)
    Remember to discharge the high voltage section before putting your hands inside!

    Serial No. ⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌋ (53-63)
    Model No. ⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌋ (64-74)

    Shop ID # ⌊_⌊_⌊_⌊_⌋ (1-4)

    Form # ⌊2⌋ (5)

    Card Sequence ⌊2⌋ (6)

    Receiver # ⌊_⌊_⌋ of ⌊_⌊_⌋ (7-10)

    Chassis No. ⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌋ (11-21)

	EIA #	Brand	Type
Picture Tube	⌊_⌊_⌊_⌋ (22-25)	⌊_⌊_⌊_⌋ (26-29)	⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌋ (30-37)
Shunt Regulator	⌊_⌊_⌊_⌋ (38-41)	⌊_⌊_⌊_⌋ (42-45)	⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌋ (46-51)
Rectifier Tube	⌊_⌊_⌊_⌋ (52-55)	⌊_⌊_⌊_⌋ (56-59)	⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌋ (60-65)

    Comments _____

4/16/70

Shop ID ⌊_⌊_⌊_⌊_⌋ (1-4)

Form ⌊3⌋ (5)

Test rig ⌊_⌊_od⌊_⌊_⌋ (6-9)

TV Repair Shop Pilot Survey

Test Rig Survey Form

1. Maximum External Reading ⌊_⌊_⌋ . ⌊_⌋ mR/hr (10-12)
   Location Code ⌊_⌊_⌊_⌋ (13-15)
   Stoms Meter # _____
   Unconverted Net Reading _____

2. (Optional) Maximum Internal Reading ⌊_⌊_⌊_⌋ . ⌊_⌋ mR/hr (16-19)
   Location _____
   Internal Meter # _____
   Unconverted Net Reading _____

To be completed only for test rigs emitting over 0.5 mR/hr externally.

3. High voltage (with all chassis controls undisturbed) ⌊_⌊_⌋ . ⌊_⌋ kV (20-22)

4. Tube Type
   EIA # ⌊_⌊_⌊_⌊_⌋ (23-26)
   Brand Code ⌊_⌊_⌊_⌊_⌋ (27-30)
   Type ⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌊_⌋ (31-38)

5/28/70

Shop ID # ____ (1-4)

Form # 4 (5)

Card Sequence # 1 (6)

TV Repair Shop Pilot Survey
Personnel Dosimetry
Facility Form

Date _____

1. Shop Name _____
   Shop Manager _____
   Street Address _____
   City, State _____
   Phone No. _____

2. Population category
   Metropolitan ___M
   Town ___T (7)
   Rural ___R

3. Team Identification ____ (8-9)

4. Is shop affiliated with a manufacturer? If so, list manufacturers and describe affiliation.
   Yes ___Y
   No ___N (10)
   _____
   _____
   _____
   _____

5. Number of full time repairmen ____ (11-12)
   Number of part time repairmen ____ (13-14)

6. Average number receivers serviced per week in shop
   color ____ (15-16)
   black & white ____ (17-18)

7. Average number of receivers serviced per week in homes
   color ____ (19-20)
   black & white ____ (21-22)

8. Number of repairmen given dosimeters ____ (23-24)

9. TLD Batch Number ____ (25-26)

Shop ID # ____ (1-4)

Form # 4 (5)

Card Sequence # 2 (6)

10. Control Badge number ____ (7-8)

Crystal #1	First reading	____	(9-12)
	Second reading	____	(13-14)
Crystal #2	First reading	____	(15-18)
	Second reading	____	(19-20)
Crystal #3	First reading	____	(21-24)
	Second reading	____	(25-26)
Crystal #4	First reading	____	(27-30)
	Second reading	____	(31-32)
Crystal #5	First reading	____	(33-36)
	Second reading	____	(37-38)
Crystal #6	First reading	____	(39-42)
	Second reading	____	(43-44)
Crystal #7	First reading	____	(45-48)
	Second reading	____	(49-50)
Crystal #8	First reading	____	(51-54)
	Second reading	____	(55-56)
Crystal #9	First reading	____	(57-60)
	Second reading	____	(61-62)
Crystal #10	First reading	____	(63-66)
	Second reading	____	(67-68)

Comments _____
_____
_____
_____

Surveyors _____

5/28/70

Shop ID # ____ (1-4)

Form # 5 (5)

TV REPAIR SHOP PILOT SURVEY

BADGE FORM

Shop Name _____

A. TO BE COMPLETED WHEN DELIVERING DOSIMETER PACKETS

1. Date ____ (6-11)
2. Serviceman's name _____
3. Initial or follow-up survey
   Initial ___I
   Follow-up ___F (12)
4. Full time or part time
   Full Time ___F
   Part Time ___P (13)
5. Performs primarily home repairs, shop repairs, or both
   Home ___H
   Shop ___S
   Both ___B (14)
6. Services primarily color receivers, black & white receivers, or both
   Color ___C
   Black & White ___W
   Both ___B (15)
7. TLD batch number ____ (16-17)
8. Badge numbers and readings
   Ring number ____ (18-20)

Crystal #1	First reading	____	(21-24)
	Second reading	____	(25-26)
Crystal #2	First reading	____	(27-30)
	Second reading	____	(31-32)
Eyeglasses badge number		____	(33-35)
Crystal #1	First reading	____	(36-39)
	Second reading	____	(40-41)
Crystal #2	First reading	____	(42-45)
	Second reading	____	(46-47)

Page 2.

	Lapel Badge Number	____	(48-50)
Calcium Fluoride	Crystal #1 First reading	____	(51-54)
	Second reading	____	(55-56)
	Crystal #2 First reading	____	(57-60)
	Second reading	____	(61-62)
Lithium Fluoride Crystal	First reading	_____	
	Second reading	_____	

Surveyors _____

B. TO BE COMPLETED WHEN COLLECTING DOSIMETER PACKETS

9. Date _____
10. Was repairman x-rayed while wearing these badges?
    Yes ___Y
    No ___N (63)
11. Were badges subjected to any unusual conditions? If so, explain.
    _____
    _____
    _____
12. About how many color sets did you repair last week? ____ (64-65)
13. What percentage of a normal work week were badges worn? ____% (66-68)
14. Were packets uncomfortable or annoying? If so, explain.
    _____
    _____
    _____

Comments _____
_____
_____
_____

Surveyors _____

APPENDIX B

ENERGY DEPENDENCE OF LARGE-AREA AND SMALL-AREA STOMS SURVEY INSTRUMENTS

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APPENDIX B

ENERGY DEPENDENCE OF LARGE-AREA AND SMALL-AREA STOMS SURVEY INSTRUMENTS

The energy dependence of these instruments is indicated by the following sets of calibration data from two typical instruments. All calibrations were performed by the Radiation Measurements and Calibration Branch, DEP.

Large-Area Stoms Survey Instrument #42
Calibration Date - 6/23/70

KeV	K Fluorescence Source	Scale Reading for 1.0 mR/hr
22.2	Ag	13.5
25.3	Sn	16.5
26.4	Sb	17.0
32.2	Ba	22.0
33.4	La	22.0
37.4	Nd	21.0
40.1	Sm	22.0
43.0	Gd	20.0
46.0	Dy	18.0
49.1	Er	16.0

Small-Area Insulated Stoms Survey Instrument #1
Calibration Date - 4/8/70

KeV	K Fluorescence Source	Scale Reading for 1.0 mR/hr
22.2	Ag	8.5
25.3	Sn	9.8
26.4	Sb	10.0
32.2	Ba	11.2
33.4	La	11.6
37.4	Nd	12.8
40.1	Sm	13.0
43.0	Gd	12.7
46.0	Dy	14.0
49.1	Er	14.0

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APPENDIX C

TLD PROCESSING PROCEDURES

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APPENDIX C

TLD PROCESSING PROCEDURES

CHOICE OF DOSIMETERS

Two types of TLD materials are commonly used by DEP: lithium fluoride (LiF) and calcium fluoride (CaF_2: Dy). These materials are commercially available under the names of TLD-100 and TLD-200, respectively, from the Harshaw Chemical Company. TLD-200 was chosen for this study because it offered two distinct advantages: First, its sensitivity is roughly 100 times that of TLD-100; second, its response is greatest and relatively constant in the x-radiation energy region of interest (20 to 35 keV) and falls sharply at the higher energy radiations which are characteristic of natural background. Because of its response characteristics, the use of TLD-200 provided an inherent discrimination factor of about 10 to 1 against natural background radiation in this study.

CONTROL PROCEDURES

Since the TLD ribbons provided the only dosimetry information in the study, it was necessary to institute appropriate control procedures to minimize the possibility of erroneous exposure indications; i.e., it was desired to measure only the exposure due to the TV radiation (if any) and to minimize or eliminate contributions from other sources. For more efficient analysis the data were compiled in a form amenable to automatic processing. The readings from the control badges were recorded on forms 1 and 4 (see appendix A), and the readings from personnel badges were recorded on form 5. This information was then transferred to punched cards for automated data processing.

Two kinds of information and control data were required: internal and external. Internal information included the batch annealing date, date sent out, date returned, dosimeter reading date and time, reader number, operator's name, and calibration data. It also included data on a set of calibrated "laboratory control" or "standard" ribbons which were taken from each batch and kept within the laboratory.

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External information included who had worn the badge, where it was worn (ring, eyeglasses, or lapel), how long it was worn, whether any other radiation exposure was received, and the dates during which it was worn.

BATCH CALIBRATION

A "batch" is a group of TLD ribbons which is annealed at the same time and exhibits uniform characteristics within predictable limits. In order to minimize the slight differences in sensitivity from one batch to another[1] which are caused by variations in internal laboratory procedures (e.g., annealing, handling, and reading, including reader performance), some of the ribbons from each batch were exposed to radiation under controlled conditions. The exposed ribbons were kept in the laboratory and used as standards for calibrating the ribbons which were returned from the repair shops.

To minimize the number of standards required, it was necessary to read out all the ribbons from a given batch at the same time. This also reduced the effect of any possible long-term changes in the reader. The problem with this practice was that the surveyor had to deliver and pick up all the badges containing ribbons from a given batch at approximately the same time. Hence, a limit was placed on the desirable batch size.

Each batch consisted of two trays of ribbons (100 ribbons per tray). After a batch of ribbons was annealed, 30 of the 200 ribbons were withdrawn and exposed to a controlled amount of radiation. The radiation source was an x-ray beam at 25 kVcp with a 3 mm of aluminum total filtration (half-value layer of 0.85 mm of aluminum). Ten ribbons were exposed to 3 mR, ten to 10 mR, and ten to 30 mR. In the absence of specific information on the exposure rate dependence of TLD-200, exposure rates of less than 1R/hr were used in the exposures. Exposure determinations were made with equipment calibrated by the National Bureau of Standards and known to be accurate within $\pm$ 2 percent. It was assumed that the energy response was the same for all ribbons and that it is represented by the typical curve given by the manufacturer (fig. 1).

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[1] In the 14 batches used for this survey, the sensitivity varied from a low of 305 reader counts/mR to a high of 385 counts/mR.

The exposed ribbons were stored at physically diverse laboratory locations (some from each exposure group in each location) to offset possible effects from systematic unintentional exposure to unknown radiation sources. The remaining ribbons were distributed to the TV repair shops. The standards were read at the same time as the rest of the batch collected from the repair shops.

READOUT PROCEDURES

The TLD ribbons were read on an Eberline TLR-5 reader in a "destructive readout" technique; i.e., once the ribbon is read out, the information is gone from the ribbon and is not recoverable. To reduce the possibility of error, two ribbons were used with each badge and were read at different times at least one day apart. Of the ten internal calibration standards for each of the three exposure levels, five were read with each of the two sets of ribbons from the same batch. Thus, the ribbons were actually read in a series of half-batches, using only one of the two ribbons from each badge and only half of the calibration standards. (The calibration standards were randomly selected from each of the storage locations).

After both ribbons from a badge were read, a comparison was made to note any differences in the readings. If the higher of the two readings for a personnel badge was more than 1.5 times the lower reading, the badge was discarded. Similarly, if the reading from a ribbon in one of the badges left in a shop to measure background radiation differed from the mean of the readings from the other nine ribbons in the same badge by a factor of two or more, that ribbon was ignored and the other nine ribbons were used to determine the background radiation in that shop.

One ring badge, three eyeglass badges, and one lapel badge were discarded because of discrepant readings. Similarly, corrections were made on four of the badges used to measure shop background.

ANNEALING AND READOUT TECHNIQUES

All annealing and reading of TLD-200 was performed by the Radiation Measurements and Calibration Branch of DEP. The standard techniques which were used are presented on the following page.

DEP Standard Annealing Technique for TLD-200

(1) Heat crystals at 400°C for one hour in stainless steel annealing tray.

(2) Remove tray from oven and let cool to room temperature (approximately one-half hour)

(3) Heat crystals at 100°C for one hour.

(4) Remove tray from the second annealing and allow to cool; the crystals are now ready for exposure.

DEP Standard Readout Technique for TLD-200 (using the Eberline TLR-5 reader)

Preheat temperature: 165°C

Preheat time: 10 seconds

Integration heating temperature: 315°C

Integration heating time: 11 seconds

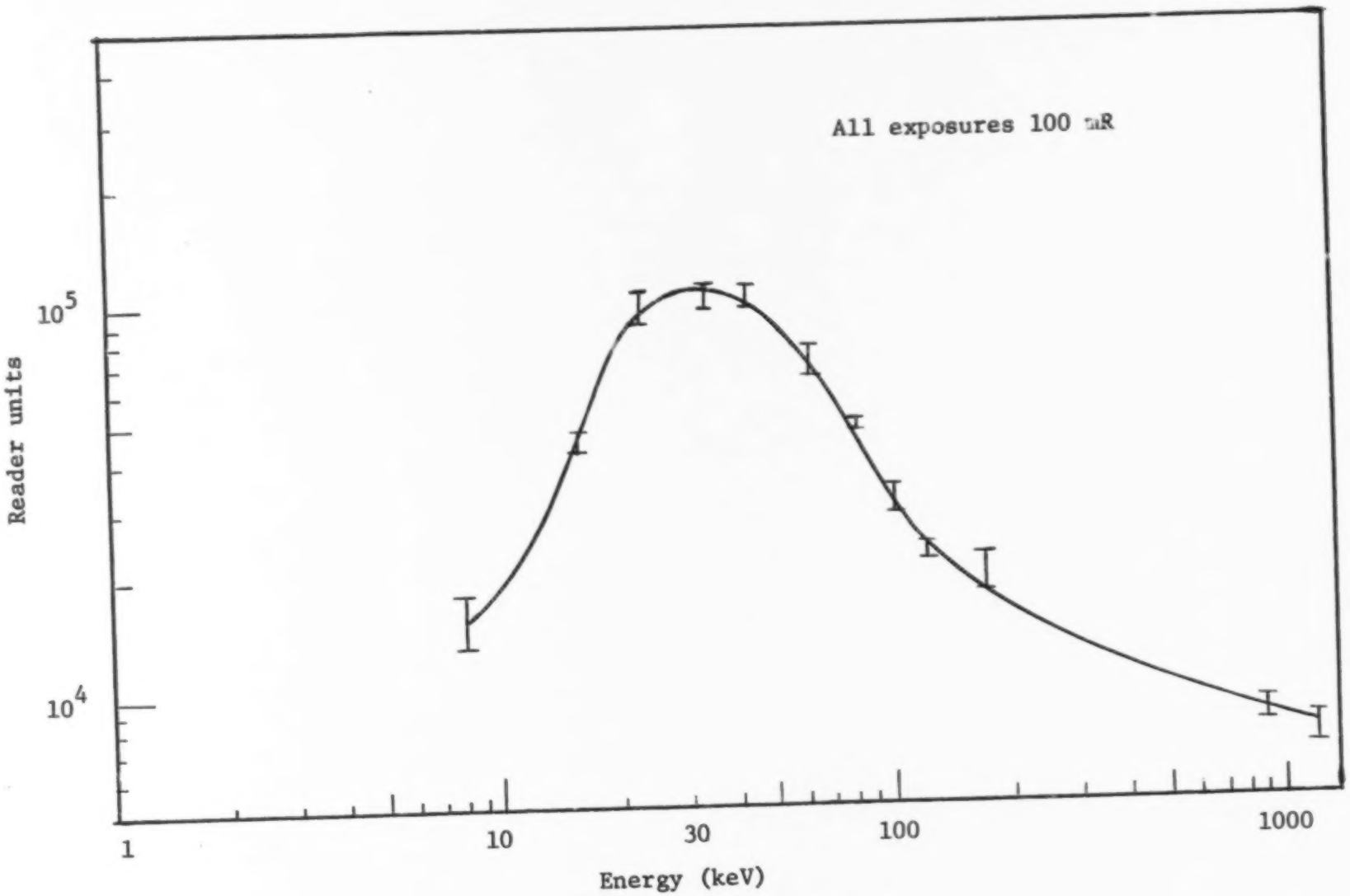

Figure 1. Energy response - TLD-200
1/8" x 1/8" x 0.035" ribbons
(Data courtesy of Battelle-Northwest)

DIVISION OF ELECTRONIC PRODUCTS

Technical Reports

(continued from inside of front cover)

	Title
BRH/DEP 70-15	A Partial Inventory of Microwave Towers, Broadcasting Transmitters, and Fixed Radars by States and Regions (June 1970) (PB 193 542 $3.00)
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BRH/DEP 71-3	Evaluation of Picker Capacitor Discharge Mobile X-ray Machine (February 1971)
BRH/DEP 71-4	A Radiation Survey of Television Repair Shops in the Baltimore Area (March 1971)